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Position Detector

The invention pertains to a position detector for detecting translational and/or rotational movements by the use of a ferromagnetic element.

Ferromagnetic elements of this type are known in the form of so-called pulse wire movement detectors from US 4,364,013 and in the form of Wiegand sensors from DE 4,107,847 C1 and DE 2,817,169 C2. In these cases, for example, a pulse wire of ferromagnetic material is surrounded by a sensor coil. The magnetic areas - also called magnetic domains or "Weiss" regions - in the ferromagnetic material are initially oriented in a random manner, but under the influence of external forces, they can be oriented into a single domain. When an external magnetic field of a certain direction and intensity is applied, this domain reverses or "flips" instantaneously. As a result, a voltage pulse which can be tapped as an output signal is generated in the sensor coil.

In a known design in the form of a rotational angle sensor (see, for example, EP 0,724,712 B1), switching and resetting magnets are conducted past these pulse wires, several of which are distributed around the circumference, so that magnetic fields first of one polarity and then of the opposite polarity permeate each of the pulse wires in

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5 succession. As a result of the remagnetization of all the
magnetic domains of each pulse wire, a voltage pulse of
defined duration, amplitude, and polarity is generated in
the sensor coil. An electronic counting circuit evaluates
these voltage pulses. The resetting magnets generate
10 fields of the opposite polarity, which return the magnetic
domains of the pulse wires to their original state, so
that the pulse wire in question is ready to trigger a new
pulse. This mode of operation is known as "asymmetric".
In symmetric mode, a pulse which can be evaluated is also
15 generated during the resetting phase.

As explained in the previously mentioned EP 0,724,712
B1, at least two of these sensors, distributed around the
circumference in the direction of movement, make it
possible to determine not only each complete revolution of
20 a rotating shaft but also, under consideration of the
characteristic positional difference between the setting
process and the resetting process, its direction of
rotation, where the voltage pulses which are generated can
be associated uniquely to the associated angular position
25 of the rotating shaft.

Because at least two sensors must be distributed
around the circumference, it is cumbersome to construct
such a system, because the pulse wire sensors must

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5 necessarily be of a certain size. This means that it is impossible to realize a revolution counter of small diameter. These sensors are also relatively expensive.

It is also known that a position detector of this type comprising only a single sensor can be used to
10 determine the revolutions of a shaft and the direction of that rotation. In this case, the sensor is designed as a Wiegand wire, which is set up at an angle to the direction of movement of a section of the shaft with a certain magnetic polarity located opposite the Wiegand wire; the
15 wire is thus able to generate a directionally dependent pulse (compare the previously cited DE 2,817,169 C2).

The disadvantage of an arrangement such as this is that, although it is possible to recognize the direction of rotation, the predetermined polarization means that
20 only the rotational direction predetermined by that polarization can be detected. That is, only one rotational direction can be determined.

So that both rotational directions of a shaft can be determined, at least two such sensors with their
25 associated evaluation circuits are therefore required. In addition, an arrangement such as this suffers under certain conditions from the disadvantage of a very low energy yield, because the angle between the direction of

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5 movement and the orientation of the sensors plays a
decisive role. An arrangement of this type therefore
makes it difficult to work without an external source of
energy.

The task of the invention is to offer a remedy for
10 this situation.

Because the interaction of the magnetic moments of
adjacent atoms with different magnetization directions is
very strong in ferromagnetic materials, the moments become
aligned with each other in small spatial areas, the so-
15 called "Weiss" regions. These regions are separated from
each other by transition layers known as "Bloch" walls.
It has been discovered that a single permanent domain with
a uniform direction of magnetization can be obtained by,
for example, mechanically stretching a ferromagnetic wire.
20 When a domain of this kind is introduced into an external
magnetic field of a certain strength and direction, the
domain does not reverse as a whole; instead, its
elementary magnets start to reverse from a certain
starting position - preferably one end of the wire - and
25 this proceeds in domino fashion in the direction toward
the external magnetic field. Although the reversal wave
thus produced in the ferromagnetic element is of finite
velocity, the velocity is high enough in comparison to the

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5 speed of the exciting magnet that it is possible to speak of an "instantaneous reversal" of the domain.

By exploiting the physical relationships described above for a position detector of the type in question here comprising at least one exciter magnet, the previously
10 mentioned task is accomplished according to the invention by means of a detector with a single ferromagnetic element, at least one induction coil, and at least one additional sensor element for the determination of information concerning the polarity and the position of
15 the exciter magnet, where the set of information available at the time of the triggering of the single ferromagnetic element is all that is needed to determine the direction of movement of the exciter magnet.

In an especially simple variant of the invention, the
20 effect of the Bloch wall passing over the ferromagnetic element makes it possible to detect the position of the exciter magnet by determining the direction in which the remagnetization of the ferromagnetic element is triggered. This remagnetization can be initiated from either one of
25 the two end surfaces of the element.

The triggering direction of the remagnetization may not be confused, however, with the direction of the remagnetization itself, which is described by the magnetic

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5 poles from and to which the Weiss regions have "flipped".
In the present case, the remagnetization direction has the effect of giving the regions in question the same polarity as that of the triggering pole of the exciter magnet.

The amount of kinetic energy which the elementary
10 magnets produce when they flip over in the direction of the external field in the form of a continuously rotating shaft is large enough that not only electrical energy for a signal pulse but also energy for a counting circuit and a Hall sensor can be taken from the coil assigned to the
15 ferromagnetic element.

Once the current position and polarity of the exciter magnet EM are known, they can be put into relationship with the most recently stored position and polarity values. This provides all the information necessary to
20 determine the direction of movement of the exciter magnet EM and the rotating shaft to which it is permanently connected.

So that the invention can be understood more clearly, it will be explained below on the basis of a revolution
25 counter.

In the general case, which is characterized by one exciter magnet and a resolution of half a revolution, the revolution counter system is described completely by four

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5 base states of the exciter magnet, these states being
combinable in various ways, in conjunction with the most
recently stored data for the magnet, namely,
Z1.) north pole to the right of the reference line,
Z2.) north pole to the left of the reference line,
10 Z3.) south pole to the right of the reference line, and
Z4.) south pole to the left of the reference line.

When only one pulse wire and an induction coil are
used according to the invention, these four states can
combine with each other in various ways to form three
15 groups of two. The group which is present in an actual
case depends on the direction in which the remagnetization
is triggered:

1st group: Both triggering directions of the
remagnetization are defined; see Figures 1, 2,
20 and 3.

- a.) north pole to the right or south pole to the left
of the reference line L (Z1 or Z4);
- b.) north pole to the left or south pole to the right
of the reference line L (Z2 or Z3).

25 The position of the exciter magnet EM can be
determined here by using the additional sensor element,
e.g., a second induction coil or a Hall sensor, to measure
the direction in which the remagnetization is triggered.

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5 This is done directly when a second coil SP2 is provided
over the ferromagnetic element FE. When a Hall sensor HS
is used, the measurement is made indirectly. When a Hall
sensor HS is used, the polarity of the exciter magnet EM
which it detects is irrelevant; the only important fact is
10 whether it is excited or not. The polarity of the exciter
magnet EM can always be found from the polarity of the
voltage pulses by using the induction coil SP1 or SP of
the ferromagnetic element FE to measure the
remagnetization direction.

- 15 2nd group: Only one triggering direction of the
remagnetization is defined; see Figure 4.
- a.) north pole to the right or north pole to the left
of the reference line L (Z1 or Z2);
 - b.) south pole to the right or south pole to the left
20 of the reference line L (Z3 or Z4).

In this case, the position of the exciter magnet EM
is always established directly by the Hall sensor, i.e.,
by the fact that it has been excited or not. The polarity
of the exciter magnet EM can be determined independently
25 of this by using the induction coil SP to measure the
remagnetization direction.

- 3rd group: No defined remagnetization triggering
direction; see Figure 5.

- 5 a.) north pole above and to the right of the
reference line L, or south pole below and to the
right of the reference line L (Z1 or Z2);
- b.) north pole below and to the right of the
reference line L, or south pole above and to the
10 right of the reference line L (Z4 or Z3).

The corresponding polarities are evaluated as a
function of the location of the Hall sensor HS, i.e.,
either on the right (as shown in Figure 5) or on the left.
The polarity of the exciter magnet EM is given here
15 directly by the Hall sensor HS. The position of the
exciter magnet EM (north pole or south pole above or
below) is now determined indirectly by measuring the
remagnetization direction.

All of the solutions are mathematically equivalent
20 and of equal technological value.

As a result of the inventive measures described
above, it is possible to realize a position detector with
the simplest imaginable mechanical design comprising only
a single ferromagnetic element, which works satisfactorily
25 in both directions of movement of the exciter magnet even
at speeds close to zero and even after the failure of the
normal power supply. The remarkable fact here is that all
of the information needed to determine the polarity and

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5 direction of movement of the exciter magnet EM is
available at time T_s , i.e., the time at which the
ferromagnetic element FE is triggered. In addition to the
stored data; therefore, all of the necessary signals are
present at the output terminals of the induction coils in
10 question and/or of the Hall sensor. For this goal to be
accomplished, it is necessary for the ferromagnetic
element FE, the Hall sensor HS, and the exciter magnet or
magnets EM to be arranged in a very specific spatial
constellation with respect to each other, e.g., in one
15 location.

A position detector with this optimally simplified
design also makes it possible to take not only the energy
for the output signals but also the energy for the
evaluation circuit, which comprises at least a counting
20 device, a nonvolatile memory, and a capacitor, from the
sensor coil SP or the sensor coils SP1, SP2.

Additional features of the invention can be derived
from the subclaims.

The invention is described below on the basis of five
25 exemplary embodiments, which are illustrated in more-or-
less schematic fashion in the drawing:

- Figure 1 shows a schematic diagram of the design of
a position detector according to the invention with one

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5 ferromagnetic element, two assigned induction coils, and
two ferromagnetic flux-conducting pieces;

- Figure 2 shows a schematic diagram of the design of
a position detector according to a second exemplary
embodiment of the invention with one ferromagnetic
10 element, one induction coil, a Hall sensor, and two
ferromagnetic flux-conducting pieces;

- Figure 3 shows a schematic diagram of a position
detector according to a third exemplary embodiment of the
invention with one ferromagnetic element, one induction
15 coil, a Hall sensor, several exciter magnets, and two
ferromagnetic flux-conducting pieces;

- Figure 4 shows a schematic diagram of a position
detector according to a fourth exemplary embodiment of the
invention with a ferromagnetic element, an induction coil,
20 and a Hall sensor;

- Figure 5 shows a schematic diagram of a position
detector according to a fifth exemplary embodiment of the
invention with a ferromagnetic element, an induction coil,
a Hall sensor, and two ferromagnetic flux-conducting
25 pieces arranged 180° across from each other;

- Figure 6 shows a block circuit diagram of an
evaluation circuit suitable for use in the embodiments
according to Figures 1-5;

5 - Figure 7 shows an arrangement of a position
detector corresponding to Figure 5, in which the
rotational axis of the exciter magnet has been rotated
90°, i.e., set up as shown in Figure 4; and

 - Figure 8 shows an arrangement of a position
10 detector corresponding to Figure 7, in which the
rotational axis of the exciter magnet has been rotated 90°
versus the arrangement according to Figure 5, where, for
the sake of clarity, two exciter magnets are shown.

 In the embodiment of a position detector shown in
15 Figure 1, the moving body is a shaft 10, which can rotate
in the directions indicated by the arrows R1 and R2, i.e.,
in either a clockwise or counterclockwise direction. So
that the revolutions of the shaft 10 can be counted, it is
provided with an exciter magnet EM with a north pole N and
20 south pole S. By way of the ferromagnetic flux-conducting
pieces FL1 and FL2, the ferromagnetic element FE can be
subjected to the influence of the magnetic field generated
by the exciter magnet EM. The ends 14 and 15 of the flux-
conducting pieces are situated on the circular arc
25 described by path of the exciter magnet EM, whereas the
end 16 (positioned to the left of the reference line L on
the FE) and the end 17 (positioned to the right of the

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5 reference line L on the FE) face the end surfaces of the ferromagnetic element FE.

The ferromagnetic element FE, which is parallel to the direction of movement of the exciter magnet, is surrounded by two sensor coils SP1 and SP2. As the
10 exciter magnet EM moves past the ferromagnetic element FE, it remagnetizes the element and thus generates voltage pulses of corresponding polarity. These pulses can be tapped from the output terminals 22 and 23 of the two coils. The second induction coil SP2 serves here as an
15 additional sensor element for determining the direction in which the remagnetization is triggered. The direction in which the remagnetization is triggered and thus the position of the exciter magnet EM can be derived from the time shift between the voltage maxima of the two coils.
20 Strictly speaking, only the coil in logical state "1" needs to be evaluated, i.e., the coil which is the first to reach its voltage maximum. The other coil has not yet reached its maximum at this point and is therefore evaluated as being in logical state "0". A pulse wire
25 serves here as the ferromagnetic element.

In the embodiment according to Figure 2, the elements which correspond to those of Figure 1 carry the same reference numbers.

5 In contrast to Figure 1, only one sensor coil SP is
assigned to the ferromagnetic element FE. So that the
position of the exciter magnet can be determined as it
passes by the ferromagnetic element, a Hall sensor HS is
provided here as the additional sensor element, at the
10 output 24 of which there either is or is not a signal
which can be tapped. The polarity is determined here as
also in the case of Figure 1 by the coil SP of the
ferromagnetic element FE. The polarity determined by the
Hall sensor is irrelevant to the evaluation, but it can be
15 used as redundant information to monitor the behavior of
the device.

 The complete set of information available at time T_s
for determining the polarity and direction of movement of
the exciter magnet therefore consists of the data in the
20 nonvolatile memory and the signals at the output terminals
of the induction coils or the signals at the output
terminals of the induction coil and the output terminals
of the Hall sensor.

 The embodiment of the position detector according to
25 Figure 3 has elements corresponding to those of the
previously described exemplary embodiments, except that
the shaft 10 has been provided here with four exciter
magnets EM1-EM4 of alternating polarity, arranged 90°

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5 apart, to increase the resolution. As the shaft 10
rotates, therefore, first a north pole and then a south
pole will be pass across each of the end surfaces of the
ferromagnetic element FE by way of the flux-conducting
pieces FL1 and FL2. The Hall sensor required to determine
10 the position of the exciter magnet is assigned here to the
ends of the exciter magnets EM1-EM4 facing away from the
ferromagnetic element.

The embodiment of the position detector according to
Figure 4 has the same elements as those of the previously
15 described embodiments, except that no flux-conducting
pieces are present here. In this variant, use is made
primarily of the fact that the ferromagnetic element FE
has already been triggered before the exciter magnet EM is
aligned with the ferromagnetic element FE. The sensing
20 range of the Hall sensor HS required to determine the
position of the exciter magnet EM is calculated in such a
way that it extends approximately up as far as the
reference line L.

The embodiment of the position detector according to
25 Figure 5 also has elements corresponding to the previously
described embodiments, except that here the ends of the
flux-conducting pieces FL1 and FL2 opposite the exciter
magnet are arranged 180° apart. The Hall sensor required

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5 as an additional sensor element to determine the polarity of the exciter magnet is here at a right angle to the reference line L passing through the center of rotation of the shaft 10 and is arranged in such a way that it is still sensing the corresponding poles of the exciter
10 magnet EM when the ferromagnetic element is triggered. This always occurs at a certain angle α before the poles become aligned with the flux-conducting pieces. The position of the exciter magnet EM is determined by the coil of the ferromagnetic element FE, which measures the
15 remagnetization direction. The present variant according to Figure 5 can operate with a very small exciter magnet EM, especially when the intended flux-conducting pieces are also used in the form of a magnetic lens to bundle the flux.

20 In the exemplary embodiments according to Figures 1-5, designs are shown in which the exciter magnet EM and the ferromagnetic element FE lie in the same plane relative to the rotational axis. It is also possible, of course, and even advantageous in certain cases for the
25 ferromagnetic element FE and the exciter magnet EM to lie in different planes - as shown in Figure 7 - or in the same plane but parallel to the rotational axis - as shown in Figure 8.

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5 The input terminals 32, 33 of an evaluation circuit,
designated overall by the reference number 30, are
connected to the sensor coils SP1 and SP2 or to the coil
SP and the Hall sensor. A circuit of this type is
assigned to each of the position detectors according to
10 Figures 1-5 and Figures 7-8. Figure 6 shows a block
circuit diagram of this evaluator. Recognition circuits
34, 35 are provided behind the input terminals. A
capacitor C for supplying energy is also connected to the
input 32 by way of the rectifier D. The signals from the
15 recognition circuits 34, 35 are evaluated in a counter 38,
which has its own nonvolatile memory 36. A new counter
status is obtained on the basis of the history contained
in the stored data and the information supplied by the
recognition circuits 34, 35 concerning the current
20 position and polarity of the exciter magnet. This new
status is then stored in the nonvolatile memory unit,
usually a FRAM unit.

 The energy for the evaluation circuit is usually
taken from the signals sent by the induction coils SP,
25 SP1, and SP2. If only one induction coil SP is used, then
the energy for the Hall sensor is also supplied by this
coil.

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5 The connecting line 41 is part of the voltage supply
for the previously described evaluation circuit. The data
can be read out via the taps 39 and an interface 40. A
line 42 - if provided - serves to bring energy in from the
outside, especially when an EEPROM is used in addition to
10 the FRAM. An EEPROM usually makes it possible for the
evaluation circuit to operate at very high temperatures,
at which configuration data in a FRAM would be lost after
only a short time.

Common to all of the previously described exemplary
15 embodiments is that the revolutions and/or rotational
direction of the shaft 10 can be detected with precision
by only a single ferromagnetic element, e.g., a pulse
wire, which also makes available sufficient energy to
supply both an evaluation circuit and a Hall sensor as an
20 additional sensor element. In the simplest variant of the
inventive arrangement of the pulse wire, according to
which the two ends of the pulse wire are equivalent in
terms of measuring technology, the generated voltage
pulses contain information on both the position and the
25 polarity of the triggering exciter magnet.

Another essential point is that all of the
information concerning the triggering direction of the
remagnetization of the ferromagnetic element, the

5 triggering pole of the exciter magnet EM, and the most recently stored polarity and position of the exciter magnet in relation to the rotating shaft is available at the triggering time T_s of the ferromagnetic element, i.e., simultaneously within the scope of the response times of
10 the selected elements.

The capacitor C in the evaluation circuit is provided to store the supply energy obtained from the signal pulses at least until the signal has been evaluated and the counter value has been stored in the nonvolatile memory
15 unit.

Instead of pulse wires or Wiegand wires, it would also be possible to use other types of ferromagnetic elements, provided that the conditions for the "instantaneous reversal" of the Weiss regions are
20 fulfilled.

To avoid misunderstanding, it should be pointed out that, ignoring stray fields, the ferromagnetic element FE is characterized by the presence of only one magnetic input and one magnetic output. Although it is conceivable
25 that there could any number of parallel and/or serial interruptions between the input and output, this would not represent a departure from the inventive idea of a single element.

5 Instead of Hall sensors, it would also be possible to
use other sensors such as field plates to determine the
polarity or position of the exciter magnet. It is also
possible to prepare the exciter magnet in such a way that
its position and/or polarity can be determined by means of
10 a capacitative measurement instead by the Hall sensor.
The use of the previously described position detector in
conjunction with a precision rotational angle sensor in
the form of a so-called "multiturn" is also possible, as
described and illustrated in, for example, EP 0,658,745.
15 In this case, the reference line L corresponds to the zero
point of the precision rotational angle sensor
being used.

When Wiegand wires, for example, are used,
synchronization with a precision rotational angle sensor
20 requires the availability of precise data on the state of
magnetization of the ferromagnetic element FE. For this
purpose, the arrangement with two coils according to
Figure 1, for example, is suitable. By supplying external
current to one of the coils, e.g., to coil SP1, it is
25 possible to trigger a voltage pulse in the second coil,
e.g., coil SP2, as a function of the magnetization of the
ferromagnetic element. This same procedure is also
possible with two coils arranged one above the other. It

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5 is also possible to trigger a voltage pulse with a short current pulse or a current with a slow linear rise, in which case only a single coil SP would be required.

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5 List of Reference Symbols

	10	shaft
	14	end
	15	end
	16	end
10	17	end
	22	output terminal
	23	output terminal
	24	output terminal
	30	evaluation circuit
15	32	input terminal
	33	input terminal
	34	recognition circuit
	35	recognition circuit
	36	nonvolatile memory
20	38	counter
	39	taps
	40	interface
	41	connecting line
	42	line
25	α	triggering angle
	C	capacitor
	D	rectifier
	EM	exciter magnet

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- 5 EM1 exciter magnet
- EM2 exciter magnet
- EM3 exciter magnet
- EM4 exciter magnet
- FE ferromagnetic element
- 10 FL1 flux-conducting piece
- FL2 flux-conducting piece
- HS Hall sensor
- L reference line
- N north pole
- 15 R1 arrow
- R2 arrow
- S south pole
- SP sensor coil
- SP1 sensor coil
- 20 SP2 sensor coil
- SE additional sensor element
- T_s time at which ferromagnetic element FE is triggered
- Z1 exciter magnet base state
- Z2 exciter magnet base state
- 25 Z3 exciter magnet base state
- Z4 exciter magnet base state

5

Claims

1. Position detector for detecting translational and/or rotational movements with at least one exciter magnet (EM), only one ferromagnetic element (FE), at least one induction coil (SP or SP1), and at least one
10 additional sensor element (SE) for determining information pertaining to the polarity and the position of the exciter magnet (EM), where all of the information needed to determine the direction of movement of the exciter magnet (EM) is available at the time (T_s) that the one
15 ferromagnetic element (FE) is triggered.

2. Position detector according to Claim 1, characterized in that the ferromagnetic element (FE) is a pulse wire.

3. Position detector according to Claims 1 and 2,
20 characterized in that the induction coil (SP or SP1) is used to measure the remagnetization direction and, in conjunction with the additional sensor element (SE), to determine the direction in which the remagnetization of the ferromagnetic element (FE) is triggered.

25 4. Position detector according to Claims 1-3, characterized in that the additional sensor element (SE) is a second induction coil (SP2) over the ferromagnetic element (FE) and is used to determine the direction in

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5 which the remagnetization of the ferromagnetic element
 (FE) is triggered.

 5. Position detector according to Claims 1-3,
characterized in that the additional sensor element (SE)
is a Hall sensor (HS) for measuring the polarity or
10 determining the position of the exciter magnet (EM).

 6. Position detector according to Claims 1-5,
characterized in that the complete set of information
available at the time (T_s) for determining the polarity
and direction of movement of the exciter magnet (EM)
15 consists of the data in the nonvolatile memory and the
signals at the output terminals (22, 23) of the induction
coils (SP1, SP2) or the signals at the output terminals
(22) of the induction coil (SP) and at the output
terminals (24) of the Hall sensor (HS).

20 7. Position detector according to Claims 1-6,
characterized in that the axis of the ferromagnetic
element (FE) is parallel to the direction of movement of
the exciter magnet (EM).

 8. Position detector according to Claims 1-6,
25 characterized in that the axis of the ferromagnetic
element (FE) is perpendicular to the direction of movement
of the exciter magnet (EM).

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- 5 9. Position detector according to Claims 1-8,
characterized in that at least one ferromagnetic flux-
conducting piece (FL1 and/or FL2) for guiding and/or
bundling the flux is assigned to the ferromagnetic element
(FE).
- 10 10. Position detector according to Claims 1-9,
characterized in that the energy supply for the evaluation
circuit (30) can be taken from the signals sent by the
induction coils (SP, SP1, SP2) used to detect position
and/or polarity.
- 15 11. Position detector according to Claims 1-10,
characterized in that the evaluation circuit (30)
comprises at least one counter (38), a nonvolatile memory
unit (36), and a capacitor (C).
- 20 12. Position detector according to Claims 1-11,
characterized in that the nonvolatile memory unit (36) is
a FRAM and/or an EEPROM unit.
- 25 13. Position detector according to one or more of
the preceding claims, characterized in that one of the
coils (SP / SP1) can be supplied with an external current
pulse, which serves either to initiate the biasing of the
ferromagnetic element (FE) or to continue that biasing.

5

Abstract

The invention pertains to a position detector which, in its simplest form of embodiment, has two induction coils but only one individual pulse wire. All information required, for example for a count, is simultaneously available from the triggering direction of the magnetic reversal and the magnetic reversal direction of the pulse wire, together with the last established and stored position and polarity. One such position detector operates using memory elements having low energy requirements, such as FRAMs, and also without external energy. In order to be able to use one such position detector even at high temperatures, it can also be fitted with an EEPROM.